The Molalla quadrangle is located in northwestern Oregon along the eastern edge of Willamette Valley about 30 miles south of Portland. The area includes part of the Western Cascade foothills as well as a portion of the Willamette Valley lowland.

The rocks in the Cascade foothills are marine and terrestrial sediments interlayered with volcanic flows and pyroclastics which range from Eocene (?) to Pliocene or early Pleistocene in age. The oldest rocks consist of approximately 1500 feet of basaltic and andesitic lavas, present in the southeastern portion of the area, and described here as the Pre-Butte Creek lavas. The base or lower part of the series contains interbedded marine pebble conglomerates presumably of Eocene age. To the southwest the lavas are unconformably overlain with about 1200 feet of marine and terrestrial sediments which have been termed the Butte Creek beds. Field relations indicate a correlation of these sediments with the Oligocene Illahe sandstone, while the faunal study made by Durham suggests a lower Miocene age. In the southwestern part of the quadrangle the Butte Creek beds are unconformably overlain by the middle Miocene Stayton lavas.

Several hundred feet of pyroclastics and terrestrial sediments considered early Pliocene in age and described as the Molalla formation are exposed along Molalla River in the eastern and northeastern part of the quadrangle. They rest unconformably on the Pre-Butte Creek lavas and are overlain by Pliocene or early Pleistocene Boring lavas.

Where exposed along the western edge of the Cascade foothills these older formations are covered by middle Pleistocene alluvial deposits which blanket the Willamette Valley lowland.

All of the Tertiary rocks have been tilted or gently folded. Dips observed in the Butte Creek beds in the southern half of the area average about 6 degrees and indicate an elongate domal fold trending northeasterly. A regional dip of 5 to 8 degrees to the northwest is present in the Molalla formation in the northern part of the area. Minor normal faulting is present locally in the Butte Creek beds.

Residual and transported high-alumina clays are present in the Molalla formation. Exploration by the United States Bureau of Mines and United States Geological Survey revealed an estimated 53,460,000 wet tons of ore in the Molalla area.
PRELIMINARY REPORT ON THE GEOLOGY OF THE
MOLALLA QUADRANGLE, OREGON

By

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A THESIS
submitted to the
OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of
MASTER OF SCIENCE

August 1946
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ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Dr. W. D. Wilkinson under whose supervision this work was done, and to Dr. I. S. Allison, both for their guidance in the field and valuable criticisms in the preparation of the manuscript. The writer is also indebted to Dr. E. L. Packard whose suggestions and criticism have been extremely helpful.

Transportation furnished by the Oregon State Department of Geology and Mineral Industries, and the helpful suggestions and assistance by Dr. W. D. Lowry in the recent field work are greatly appreciated.

Grateful acknowledgment is also made to Dr. J. W. Durham and Dr. H. E. Vokes for their identification of fossils collected from the area, and to Beverly Wilder and members of the 1941 Summer Field course who assisted in the mapping.
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PRELIMINARY REPORT ON THE GEOLOGY OF THE
MOLALLA QUADRANGLE, OREGON

INTRODUCTION

The accompanying preliminary geologic map of the Molalla quadrangle was prepared during the summer of 1941. The field work was undertaken by a group of students, including the writer, under the direction of Dr. W. D. Wilkinson of Oregon State College, as a joint project with the Oregon State Department of Geology and Mineral Industries. Laboratory studies of the specimens collected were made by the writer, and part of the manuscript was prepared during the latter part of the summer. The work was not completed, however, and all of the material, with the exception of the specimens and field map, was subsequently destroyed by fire. In an effort to salvage as much as possible from the loss, the area was recently revisited and the following summary descriptions prepared.

PREVIOUS WORK

Few references to the geology of western Clackamas County are contained in the writings of the earlier observers of geology in northwestern Oregon. Washburn (21) in 1914 referred to 400 feet of marine strata and 600 to 700 feet of apparently conformably overlying terrestrial sediments in the vicinity of Coal Creek near the southern edge of the quadrangle. Fossils collected from these lower marine sandstones at a locality on Coal Creek were identified by Arnold, and considered to be Oligocene in age. The marine sequence
was described as resting on a basic igneous rock which extended down
the Butte Creek canyon to Scotts Mills where it was unconformably
overlain by marine sandstones and conglomerates of Miocene age.

In 1934 Thayer (14) described the geology of the Western
Cascades along the North Santiam River south of the Molalla quad-
range, and O'Neill (13) in 1939 described the geology of the Stayton
quadrange.

Treasher (17, 18) in 1942 described the geology of the Portland
area which includes the Oregon City and Boring quadrangles adjoining
the Molalla quadrangle on the north.

Beverly Wilder is preparing a doctorate thesis at the University
of California on the flora collected from the Molalla formation in
1941.

Exploration of the Molalla clay deposits was made during 1942
and 1943 by the United States Bureau of Mines and the United States
Geological Survey.

LOCATION AND ACCESSIBILITY

The Molalla quadrangle is located in the lower Cascade foothills
along the eastern edge of the Willamette Valley approximately 30
miles south of Portland. The southwest corner of the quadrangle lies
along the northern boundary of Marion County and the remainder is in
the western part of Clackamas County. The area is bounded by the
meridians 122°45' and 122°30' west, and the parallels 45°00' and
45°15' north.
Except for parts in the southeastern corner of the quadrangle, the area is readily accessible by paved highways and a network of market roads. Pacific Highway 99E extends across the northeast corner of the area south of Canby. State Highway No. 211 extends from Silverton, 2 miles southwest of the area, northeastward to Molalla and thence eastward to Colton and Estacada. State Highway No. 215 extends north from Molalla to Oregon City where it joins Pacific Highway 99E.

GEOLOGY AND STRATIGRAPHY

The foothills of the Western Cascades in the area are composed of marine and terrestrial sedimentary rocks interlayered with volcanic flows and pyroclastics which range from upper Miocene (?) to late Pliocene or early Pleistocene in age. The oldest formation is a lava series which covers an extensive area in the southeastern part of the quadrangle and is here referred to as the Pre-Butte Creek lavas. To the southwest these lavas are unconformably overlain by approximately 1200 feet of Oligocene or lower Miocene (?) marine and terrestrial sediments which are described as the Butte Creek Beds. These are in turn unconformably overlain by the middle Miocene Stayton lavas.

Several hundred feet of pyroclastics and terrestrial sediments described as the Molalla formation are exposed along the Molalla River in the east and northeastern part of the area and are considered early Pliocene in age. They rest unconformably on the Pre-
Butte Creek lavas and are overlain by the late Pliocene or early Pleistocene Boring lavas.

Where exposed along the western edge of the Cascade foothills, these older formations are covered by middle Pleistocene alluvial deposits which blanket the extensive lowland portion of the quadrangle.

Pre-Butte Creek Lavas

The Pre-Butte Creek lavas occupy the area northwest of Wilhoit, and the ridges along the Molalla River to the east and southeast. Small isolated patches are exposed along Butte Creek about 3 miles east of Scotts Mills.

The lavas consist predominantly of dark to light gray, platy porphyritic andesites. Basalt and a minor amount of tuffs and breccias are present in the lower portion of the lava series. Tabular feldspar phenocrysts ranging in size up to 6 millimeters in length are characteristic of the platy, porphyritic andesites. The lavas in the vicinity of Wilhoit and along Butte Creek, although porphyritic, are darker in color and are largely basalts. In these lavas the mafic minerals have altered to chlorite; and amygdals of calcite, epidote, and zeolites are common in the vesicular phases.

In the occurrence east of Scotts Mills, rounded basaltic cobbles, as much as 8 inches or more in diameter, are embedded in the lava, and an indistinct pillow structure is developed. Interbedded with the lava are thin beds of pebble conglomerates and tuffaceous marine
sandstones. This evidence suggests that the lavas in this occurrence represent the base or lower portion of the series. Fossils from the interfingerling conglomerates have been identified by Dr. H. E. Vokes (19) as *Ficopsis* sp. and *Molopophorous (?)* sp undet. He believes the *Ficopsis* to be the shouldered type suggestive of *Ficopsis meganosensis*, and considers the sediments to be of Eocene age.

The presence of presumed Eocene sediments in the Butte Creek locality is not indicated on the map; and their extent, although considered small, is not known since they were observed only recently when the area was revisited.

The entire section of the lavas is not shown in any one locality. The darker, more highly altered lavas are best exposed along Rock Creek northwest of Wilhoit. They appear to grade upward into the gray porphyritic andesites which are well exposed in cuts on the logging road along the west side of Molalla River just east of the area.

The entire thickness of the series is not known. Approximately 1500 feet are exposed within the quadrangle, and the thickness apparently increases to the southeast. To the west, the lavas are unconformably overlain by marine sandstones and tuffs of Oligocene or lower Miocene age, and along the Molalla River southeast of the area, they are disconformably overlain by Columbia River basalts. On the basis of the fossils in the interbedded marine sediments on Butte Creek, the lower part of the series is tentatively considered
Eocene in age, and the upper andesitic portion may in part be Oligocene. Although the lavas were traced to within a few miles of the Mehama volcanics and Sardine series in the North Santiam River area, the relationship is not known and a correlation cannot be made. It appears likely, however, that the upper andesitic portion of the lavas may be equivalent in age to the Mehama volcanics.

**Butte Creek Beds**

The name Butte Creek Beds has been proposed here for several hundred feet of marine and terrestrial sedimentary rocks which cover an extensive area southeast of Marquam and are exposed along Butte and Abiqua Creeks.

The beds are composed mainly of rather well bedded tuffaceous marine sandstones which appear to interfinger with, or grade upward into terrestrial sediments which range from conglomerates to fine-grained tuffs and ash. Small patches of impure shell limestone are present and thin coal beds and carbonaceous shales are numerous. The medium-grained sandstones are bluish or greenish gray in fresh exposures and weather to various shades of brown. Blocky jointing is developed in the massive sandstones and spheroidal weathering is common in some of the more resistant beds.

Marine fossils are abundant in parts of the sandstone series and have been collected from four of the best localities. The locality on Butte Creek is an exposure in a quarry about 3½ miles southeast of Scotts Mills on the road which runs along the north
side of Butte Creek. A fairly large fauna is present at this locality but most of the fossils are crushed and flattened. Two other localities are in the vicinity of the Beaver Creek school. Both are road-cut exposures; one about 0.7 mile east of the school on the road leading to Wilhoit, and the other one mile west of the school on the road to Scotts Mills. The fourth locality is at the Marquam limestone quarry about 2 miles northeast of Marquam. Identifiable fossils can be obtained from the limestone which is an aggregate of shell fragments. Fossils from the above localities were identified by Dr. J. W. Durham (8) as listed below:

- Bruc Clarkia sp. (apparently near B. oregonensis)
- Molopophorus sp.
- Polinices sp.
- Pecten sespeensis Arnold
- Spisula catillifornis Conrad, var.
- Tellina oregonensis Conrad
- Apolycthis sp.
- Cryptomya sp. (cf. californica)
- Siphonilia n. sp.
- Mytilus cf. arnoldi Clark
- Solen sp.
- Spisula alberia Conrad
- Tereis harfordi (Anderson)?
- Thracia sp.
- Velsella poterensis (Clark)?

Fossils are present also on Coal Creek near its junction with Butte Creek, along Butte Creek at Scotts Mills, near the basalt sandstone contact west of Wilhoit, and at other smaller exposures throughout the area.

The Butte Creek beds rest unconformably on the Pre-Butte Creek lavas. The base is best exposed in the area northwest of Wilhoit and along Butte Creek a few miles southeast of Scotts Mills where it
rests on an isolated patch of the older lavas and interbedded Eocene marine sediments. The Eocene sediments associated with the older lavas may be more extensive than now recognized and some of the sandstones mapped as Butte Creek beds may be Eocene. Disregarding this possibility, the estimated thickness of the Butte Creek beds is about 1200 feet.

The Butte Creek beds can be traced into the Stayton quadrangle to the southwest where they have been mapped by O'Neill (13) and Thayer (16) as the Illahe formation. Thayer considers the Illahe formation to be the equivalent of the Eugene or Pittsburg Bluff formations of middle Oligocene age.

On the basis of the fauna, however, Durham (9) has determined the age of the Butte Creek beds as lower Miocene. On the basis of Pecten sspencesis Arnold, he believes them most likely equivalent in age to the Vaqueros formation of California. This would necessitate the extension of a Miocene seaway a considerable distance farther east than has heretofore been recognized. Durham (9) has suggested the possibility that the marine sediments were deposited in an initial stage of the Miocene Astoria seaway which entered the Willamette area from the north or northwest. The nearest Miocene sediments to the west with which the seaway would connect is the Scappoose formation (20) of probably lower Miocene age, and the Astoria Miocene (22) in Columbia County and southwestern Washington.

The field evidence available at present indicates a close correlation with the Illahe or other marine Oligocene sediments in
the Willamette Valley; but in view of the possible lower Miocene age of the sediments on the basis of the faunal study, the name Butte Creek beds was used. Because of the compressed and fragmental nature of the fossils from most of the localities, the identification is difficult, and extensive collections will have to be made before more exact correlations can be established.

**Stayton Lavas**

The Stayton lavas are present along the western edge of the Cascades in the southwestern part of the quadrangle. Isolated cappings north of Butte Creek appear to be the northern extent of the lavas which extensively cover the Waldo Hills in the Stayton quadrangle to the southwest. O'Neill (13: p. 25) reports an average thickness of 200 to 400 feet in the Waldo Hills and indicates a maximum thickness of 575 feet south of Silverton. The thickness apparently increases to about 700 feet along Abiqua and Butte Creeks and then decreases rapidly to the northeast.

The Stayton lavas within the area are composed mainly of dark gray to black aphanitic or finely porphyritic basalts. Unusually large skeletal crystals of magnetite and an abundance of magnetite dendrites and dust are present in the basalt on Butte Creek just east of Scotts Mills, which appears to be typical of the black Stayton lavas described by O'Neill. Petrographic descriptions given by O'Neill (13: p. 26-34) indicate a rather wide variation in the lavas in the Stayton quadrangle. Chemical analyses of the typical
black and gray Stayton lavas have been given by Thayer (15: p.1622)
The Stayton lavas unconformably overlie the Butte Creek beds of Oligocene or lower Miocene (1) age. The lavas poured out on an erosional surface, having a relief of several hundred feet. Individual flows could not be traced with any certainty and reliable dips were not obtained. Intrusive basalt resembling the Stayton lavas in megascopic appearance have cut the Pre-Butte Creek lavas and the Butte Creek beds, and are probably equivalent in age to the Stayton lavas.

The Stayton lavas were named by Thayer for their abundant exposures near the city of Stayton. Thayer (15: p. 1617) assigned the lavas to the middle Miocene and correlated them with the Columbia River basalts. In discussing their correlation, Thayer stated, "They resemble the Columbia River basalts in general character, and their thickness, as it increases toward the northeast, approaches that of the Columbia River basalt exposed in the Mehama anticline where the Clackamas River crosses it. The Stayton lavas also interfinger with and might be considered part of the Sardine series, which is probably equivalent to the Columbia River basalts, for the basalts were traced to the southern edge of the Estacada quadrangle by Barnes and Butler, and the writer mapped the Sardine lavas within 5 miles of the same point. The regional structure shows such continuity that the two lava series must be stratigraphically equivalent with interfingerling flows." The typical Columbia River basalt along the Molalla River southeast of the area may be the same as that mapped by Barnes and
Butler, but since it was not traced westwardly to connect with the Stayton lavas, the present study has added nothing to the correlation.

Molalla Formation

The name Molalla formation has been proposed for several hundred feet of terrestrial sediments which are exposed along the Molalla River east of the town of Molalla. Except for the higher hills which are capped with Boring lavas, the formation covers most of the north-eastern part of the quadrangle and presumably underlies the veneer of Pleistocene gravel and silt that forms the floor of the Willamette Valley in the northwest portion of the area. The best exposures of the formation can be seen along the logging road on the west bank of the Molalla River 2½ miles southeast of Molalla.

The sediments comprising the Molalla formation cover a wide lithologic range. They consist of tuffaceous sandstone, conglomerates, tuffs, breccias, agglomerates, sand, gravel, silt and clay.

The groundmass of the tuffs and tuffaceous sediments consists primarily of devitrified flakes, shards, and sickles of glass. Most samples show extensive kaolinization. Pumice is generally present in most of the tuffs and in places becomes the principle constituent in massive coarse tuffs and pumiceous breccias. The pebbles and cobbles in the conglomerates are dominantly igneous in origin and consist mainly of basalts and porphyritic andesites. The cobbles and boulders are generally well rounded, and are present in all sizes up to a foot or more in diameter. In most exposures along the
Molalla River, southeast of Molalla, the conglomerates are highly weathered and in many cases the entire bed has been completely altered to clay. Crossbedded sandstones and pebble conglomerates exposed along the Molalla River and Milk Creek north of Molalla are less tuffaceous and are weathered to a much less degree than the conglomerates mentioned above.

A coarse volcanic breccia is exposed at the Molalla Bridge 3 miles east of Molalla. The breccia is exposed for a mile and a half along the east bank of the river and covers an area about a half mile in width. The breccia is well indurated and consists of unsorted angular basaltic blocks set in a tuffaceous, clayey matrix containing small angular to sub-rounded fragments of volcanic rock. The blocks range in size up to four feet or more in diameter. Fragments of wood and casts of limbs several inches in diameter are numerous. In drilling the clay area two and a half miles southeast of Molalla on the west side of the river, Nichols (12) reported the presence of unsorted and unstratified breccia which he believed equivalent to the breccia at the Molalla Bridge. He is of the opinion that they were deposited as a series of mud flows. Coarse breccias of similar appearance are present along State Highway No. 211 to Colton and Estacada east of the area.

Fossil leaves are abundant in the thin beds of carbonaceous shales and fine-grained tuffaceous phases of the formation. Extensive collections were made in 1941 by Beverly Wilder of the University of California, and about 38 species of plants have been identi-
Lenticular structures and crossbedding are characteristic of the gravelly phases of the formation with foresets dipping up to 25 degrees. Dips in the more massive beds average about 5 degrees to the northwest.

The Molalla formation unconformably overlies the Pre-Butte Creek lavas. The relationship of the Molalla sediments with the older lavas is not clearly shown within the area. The heavy soil mantle, local slumping, and dense vegetation obscure most of the contacts. The distribution of the sediments with relation to the porphyritic andesites which crop out along the Molalla River at higher elevations led most observers, including the writer, to believe that the sediments were interbedded with, or overlain by the andesites. New road cuts along the west side of the Molalla River a mile east of the area expose tuffaceous sediments, conglomerates, and breccias resting on an erosional surface of the porphyritic andesite. These sediments and others of similar appearance occurring at higher elevations along the west side of the canyon are considered part of the Molalla formation and were probably deposited as a valley fill.

The Molalla formation is quite similar in composition, degree of weathering, and other characteristics, to the Fern Ridge tuff in the Stayton quadrangle and along the North Santiam River south of the area. In his study of the clays in the Molalla and Salem districts, Treasher (23: p.40, 48) found that the clays appeared to lie at or near the base of the Fern Ridge tuffs, and therefore tentatively
correlated the tuffs overlying the Molalla clays with the Fern Ridge tuffs. Treasher (23: p. 48) considered the Fern Ridge tuffs to be upper Miocene, as originally assigned by Thayer (16: p. 8) who believed the tuffs to be conformable upon the Stayton lavas. O'Neill, (13: p.44), however, concluded from a later study in the Stayton quadrangle that the Fern Ridge tuffs were younger than upper Miocene, since he found them deposited on a mature topography, and therefore tentatively assigned the tuffs to middle Pliocene.

The present study substantiates the tentative correlation of the Molalla formation with the Fern Ridge tuff as assigned to the Pliocene. It is also in part probably equivalent in age to the Troutdale formation. The Molalla sediments differ from those of the Troutdale formation in the absence of quartzite pebbles and a greater abundance of clays and tuff. The pyroclastics and associated sediments comprising the two formations were derived from different sources but the topographic and stratigraphic relations, and the general similarity of the upper portion of the Molalla formation with the Troutdale formation suggests simultaneous deposition.

An early study of the Molalla flora by Wilder (9) indicated the sediments were lower Miocene in age. Whether his more recent studies will tend to substantiate the younger Pliocene age indicated by the stratigraphy is not known.

**Boring Lavas**

The Boring lavas form the cappings of the low rolling hills in
the northeast corner of the quadrangle. They cover extensive areas in the Oregon City and Boring quadrangles to the north and northeast.

The lavas are predominantly fine-grained, light to dark gray in color, and are characterized by the presence of olivine. The olivine is partially altered to limonite and is recognized in hand specimens as tiny reddish brown specks. The olivine phenocrysts observed in thin section are euhedral crystals set in a groundmass of feldspar laths and a small amount of colorless to light brown glass. All of the olivine phenocrysts show varying amounts of alteration to iddingsite and limonite. The lavas are further characterized by a porous texture which Treasher (17: p. 10) has described as inflated. Vesicular phases are common and both columnar and blocky jointing are well developed.

The Boring lavas unconformably overlie the Molalla formation. The lavas were deposited on a surface having a maximum relief of about 500 feet within the area mapped. Individual flows could not be traced, and other than a few observations which suggest initial westerly dips, reliable dips were not observed. Treasher (18) found the dips in the Portland area varied widely within short distances and considered them largely initial.

The Boring lavas were named by Treasher (17: p. 10) for their occurrence in the Boring Hills southeast of Portland. They unconformably overlie the Troutdale formation in the Portland area and are considered by Treasher to be late Pliocene or early Pleistocene in age.
Pleistocene and Recent Alluvial Deposits

Alluvial sands, silts, clays, and gravels deposited during the Pleistocene epoch, and the Recent deposits along the flood plains of present streams cover more than a third of the total area in the Molalla quadrangle. These deposits form four distinct mappable units. They include two gravel deposits, possibly of Kansan or early Wisconsin age, respectively, the Willamette silt, which forms the most extensive of the alluvial deposits, and the Recent flood plain deposits.

Since the gravels were not studied in sufficient detail to permit a definite correlation with other Pleistocene gravels in the Willamette Valley, they were not assigned formational names and will be referred to as Number 1 and Number 2 gravels.

Number 1 Gravels. The Number 1 gravels occur south of the town of Molalla where they cover an area of about 3 square miles, and also on the east side of Molalla River where they cover a somewhat smaller area. These two areas are considered remnants of an extensive alluvial fan or flood plain deposit which accumulated in middle Pleistocene time. The western boundary of the deposit on the east side of Molalla River is a rounded, yet well defined escarpment rising an average of about 40 feet above the adjacent younger Number 2 terrace gravel. The deposit is dissected and forms a gently rolling surface between 600 and 700 feet in elevation.

South of Molalla on the west side of the river, the boundaries of the gravels are very indistinct since they seem to merge in...
physiographic expression and in general appearance with the Molalla formation. The gravels there form a thin veneer which has been dissected and eroded to a gently rolling surface. Partially weathered cobbles of basalt or andesite are commonly present in the soil developed on the gravels and were one of the principal aids used in the mapping.

The eastern part of this gravel surface is included in the area explored by the United States Geological Survey and the United States Bureau of Mines for high-alumina clay.

The Number 1 gravels consist essentially of basalt and andesite pebbles and cobbles. Oxidation has proceeded to a depth of 20 feet or more and most of the pebbles and even cobbles up to 6 inches in diameter in the upper part of the weathering profile have been softened to such a degree that they may be readily cut with a knife.

At the southern edge of the area south of Molalla, these gravels lie on the Pre-Butte Creek lavas and in all other places, on the the Molalla formation. They form the oldest, well-defined gravel deposit in the area and on the basis of their topographic position, amount of subsequent erosion, and degree of weathering, Allison (4) considers them to belong to the Kansan or Sherwin stage of the Pleistocene.

Number 2 Gravels. The Number 2 gravels form an extensive alluvial fan upon which the town of Molalla is situated. The well defined fan form of the deposit, which is the most conspicuous physiographic feature in the quadrangle, is excellently delineated on the
topographic map. The gravels, deposited by the Molalla River, extend upstream to a point about a half mile west of where the river enters the quadrangle. The river has cut through the upper portion of the deposit leaving the extreme apex of the fan separated from the major portion of the fan. Other streams are entrenched upon the surface of the fan and radiate northwesterly from the highest part of the fan on the west side of the river near Molalla. The slope of the deposit averages approximately 50 feet per mile.

The gravels consist predominantly of pebbles, cobbles, and boulders of basalt and andesite. The average pebble size is 2 inches. Boulders, as much as 2 feet in diameter, are present in exposures east of Molalla. Lenses of sand are common and much of the pebbly gravel appears to be well sorted.

Oxidation has extended to a depth of about 6 feet in most exposures. The pebbles and cobbles generally have a soft rind 3 or 4 millimeters in thickness and can be easily scratched with a hammer.

Where the Molalla River has cut through the deposit, the gravels are seen to lie on the Molalla formation. They are younger than the Number 1 gravels, having been deposited on an alluvial surface at a lower elevation. On the basis of the topographic position, degree of weathering, and their relation to the Willamette silts and older gravels, Allison (5) believes the Number 2 gravels were deposited during the early Wisconsin or Tahoe stage of the Pleistocene.

Prior to deposition of the Willamette silt, the Molalla River entrenched itself in the deposit along the northeastern edge of the
fan, thereby producing a conspicuous erosional terrace which extends for several miles along the present course of the river north of Molalla. The terrace averages 3/4 mile in width and has a slope of approximately 40 feet per mile. The southern boundary of the terrace is marked by a rounded escarpment 10 to 15 feet in height which becomes lower and indistinct to the northwest where it is obscured by the veneer of Willamette silt. Its eastern boundary is marked by an escarpment 20 to 30 feet in height where the river has cut through the Willamette silt and underlying gravels.

The gravels extend under the Willamette silt north as well as south of the Molalla River. In the vicinity of Mulino, between Molalla River and Milk Creek, the terrace extends over an area of about 3 square miles but the gravels are poorly exposed because of the heavy silt mantle.

**Willamette Silts.** The Willamette silt and related deposits are the most widespread of the alluvial deposits in the area. Except for recent alluvium, the Willamette silt deposits cover the Willamette Valley lowland which extends over most of the western half of the quadrangle. The silts lap upon the Number 2 gravels and older formations along the eastern edge of the Willamette Valley lowland to an elevation of about 325 feet. Above this elevation, the silt deposits are thin and their distribution is not generally shown on the areal map.

The Willamette deposits are composed mainly of silt and fine sand and considerably differ from the older alluvial deposits in the
area in texture, composition and other characteristics. The fine material consists of angular grains of quartz, feldspar, mica, garnet, and a variety of other minerals, some of which are foreign to the Willamette drainage basin. Coarser material, commonly found scattered over small areas, consist of granitic rocks, quartzite, schists, and other metamorphic rocks. These pieces range in size from small angular fragments to blocks several feet in diameter. Allison (3: p. 615-632) has described the occurrence of the erratics in the Willamette Valley and has assigned the source of the foreign material to the upper drainage basin of the glacial Columbia River.

The Willamette deposits, for the most part, were deposited from an open body of water in the form of a sheet of silt and fine sand. The material was deposited on the older sedimentary and volcanic rocks which form the lower slopes of the Western Cascades as well as upon the Number 2 alluvial gravels and the terrace eroded into this surface. Coarse gravels and sands associated with the silt in the vicinity of Canby and extending into the northwest corner of the quadrangle were considered by Allison (2) to have been deposited by Columbia River flood waters which entered the Willamette Valley through the Oregon City gap.

The name Willamette silts was suggested for these deposits by Allison, because of the typical Willamette soil series which was developed on much of their surface. The name was first applied to the deposits by Felts (7). On the basis of their topographic and stratigraphic relations, the profile of weathering of the silts, and the
degree of weathering of the erratics, Allison (3: p. 627-631) assigned the erratics and associated silts to the Wisconsin stage of the Pleistocene.

Recent Deposits. Recent deposits of sand, silt, and gravel along Molalla River and some of the smaller streams in the area are sufficiently thick to warrant mapping. Low cut-terraces along the Molalla River, which are probably somewhat older than the recent flood plain deposits, are included on the map with the Recent deposits. The largest of these has an average width of one half mile and extends for a distance of 7 miles along the west side of Molalla River north of the town of Molalla. The terrace lies between the base of the high escarpment cut in the Number 2 alluvial gravels and the present flood plain. A similar terrace is present along the east side of Molalla River in the vicinity of Collins Camp. It extends along the river for a distance of about 2 miles and is about three quarters of a mile in width.

STRUCTURE

In mapping the North Santiam section, Thayer (16: p. 13) found the northern portion of the Western Cascades compressed into a series of gentle folds trending northeast to north, all of which apparently plunge northward at low angles. The area of the Molalla quadrangle lies between the western most of these structures, the Willamette syncline, and the Mehama anticline. The projected axis of the Willamette syncline would pass just west of the northeast corner of the quad-
rangle, and the axis of the Mehama anticline as projected by Thayer to the Clackamas River, would lie about 10 miles southeast of this area.

Dips observed in the southern half of the Molalla quadrangle indicate an anticline or elongate domal fold lying between these two structures with a northeasterly trend parallel to the trend of the Mehama anticline. Westerly dips which average about 6 degrees were observed in the Butte Creek marine sandstones in the vicinity of Beaver Creek School, along Butte Creek west of Scotts Mills, and along Abiqua Creek near the southern edge of the area. Dips vary from 1 to 8 degrees east in a coal seam about a mile east of Wilhoit, and southeasterly dips of from 3 to 11 degrees were observed in the terrestrial sediments and fossiliferous sandstones on Coal Creek, and on Butte Creek 4 miles southeast of Scotts Mills. On the basis of these dips, the axis of the fold would cross Butte Creek 2 or 3 miles east of Scotts Mills and extend northeasterly to Wilhoit.

Minor faulting with a vertical displacement of not more than 3 feet, was observed along the old railroad grade in the southeast corner of the quadrangle. Basaltic dikes have cut the Pre-Butte Creek lavas and overlying sediments along Butte Creek and slickensides and local tilting were observed along the contacts. Slumping has occurred at several places in the Butte Creek beds near the contact of the overlying Stayton lavas.

Thayer (16: p. 35) has dated the folding of the Western Cascades as upper Miocene. Callaghan and Buddington (6) likewise assigned the
folding and minor faulting to upper Miocene, while Hodge (10) believed the deformation of the John Day-Columbia River basalts took place in early Pliocene time. According to Thayer (16: p. 10) the folding was followed by a series of uplifts which elevated the Western Cascades to its present elevation before deposition of the High Cascade lavas.

MINERAL DEPOSITS

Clay

The most extensive mineral deposits in the area are the clay deposits. These deposits are found mainly in the Molalla formation and are located in the area between Molalla and the eastern boundary of the quadrangle along the west side of Molalla River.

An investigation and exploration of the clay deposits in this area as a possible source of alumina was conducted as a joint project by the United States Geological Survey and the United States Bureau of Mines (24) in 1942 and 1943. Seventy-seven holes with a total footage of 7,963 feet were drilled throughout this area. This investigation revealed an extensive deposit about 2 miles southeast of Molalla. The deposit is in the form of two clay series separated by low-grade material averaging 42 feet in thickness (24: p. 3). The upper and lower clay series average 50.7 and 51.5 feet respectively in thickness. On the basis of the drilling the United States Bureau of Mines (24: p. 7) has shown an estimated 19,810,000 wet tons of
of high quality clay in the upper series, 19,560,000 wet tons in the lower clay series, and an additional 5,340,000 and 8,750,000 wet tons respectively in the "North Area" and "West Area". Calculated on a dry basis, the upper clays contain 25.4 percent alumina and 7.9 percent Fe₂O₃, and the lower clay contains 27.9 percent alumina and 8.5 percent Fe₂O₃. The moisture content of the clay is approximately 34 percent.

The deposits are composed of both residual and transported clays and are interbedded with conglomerates, tuffaceous sediments, and breccias which in places have been so altered that they contain as much available alumina as the clays.

Other deposits southeast of the area drilled by the Bureau of Mines have been described by Treasher (23: p. 40-49) and Hodge (11). These deposits are less extensive than the one explored by the Bureau of Mines but are of similar quality clays.

Coal

Deposits of coal have been found in tuffaceous sediments in the vicinity of Wilhoit, and along Coal Creek near the southern edge of the quadrangle. Very thin beds of coal, interbedded with thin layers of carbonaceous shale, are exposed along the old railroad grade in the southeast corner of the area.

The most developed prospect is located about one-half mile east of Wilhoit Springs in the W½ sec. 15, T 6 S., R 2 E. According to Allen (1), who examined the prospect in 1944 for the State Department
of Geology and Mineral Industries, the coal bed is from 7 to 9 feet thick and lies within tuffaceous beds which have a regional dip to the east. The strike is a little east of north and the dip varies from 0 to 8 degrees. He found that the Coal ranks as a bituminous coal, in the high volatile C class, but because of the interbedded shaley material in the upper portion of the bed, the high grade coal could not be mined and sorted to sell at a profit. A small tonnage of coal was produced incidental to development work during 1943 and 1944.

The prospect on Coal Creek is located on the west side of the creek about 1/4 mile north of the southern boundary of the quadrangle. The coal bed is about 2 feet thick and dips 11 degrees to the south-east. The coal appears to be of a bituminous grade, but like the Wilhoit coal, is interbedded with carbonaceous shale.

At Scotts Mills, a five foot bed of coal was reportedly encountered in a 1000 foot, 35 degree incline shaft. The work was done over 30 years ago and reliable information regarding the thickness, extent, and grade of coal was not obtained.

**Limestone**

Thin beds of impure shell limestone are present in the marine Butte Creek beds east of Marquam and in isolated occurrences along Butte Creek, east of Scotts Mills. At the site of the Marquam Limestone quarry, 1½ miles northeast of Marquam, the beds are nearly horizontal and average about 9 feet in thickness. The limestone is
present in two localities and on the basis of exploratory drilling is considered to extend over a total area of approximately 15 acres. The limestone averages less than 70 percent CaCO₃ and is quarried principally for agricultural use.

The shell limestone on Butte Creek is considered of little commercial value but has been locally used as a source of lime.
PLATE I

MOLALLA QUADRANGLE

LEGEND

QA
RECENT ALLUVIUM

QW
WILLAMETTE SILT

QWG
NO. 2 GRAVELS

QW
NO. 1 GRAVELS

QTV
BORING LAYERS

UNCONFORMITY

TM
MOLALLA FORMATION

UNCONFORMITY

TB
STAYTON LAVAS

UNCONFORMITY

Te
PRE-BUTTE CREEK LAVAS

MOLALLA, OREGON
BIBLIOGRAPHY

1. Allen, J. E. Personal communication, July 1946.


5. Allison, I. S. Personal communication, July 1946.


19. Vokes, H. E. Personal communication, July 1946.


